Object Based Attention in Illusory Figures

Helden, Jurjen van der

Publication date:
2005

Summary and General Discussion

6.1 Summary

Many researchers have studied space-based and object-based selection in the past few decades by focusing on effects in performance (Posner, 1980; Posner et al., 1984; Scholl, 2001; Kanwisher and Driver, 1992; Driver and Baylis, 1998). In ERP research, however, mainly space-based selection has been studied (for reviews see Mangun, Hillyard, and Luck, 1993; Mangun, 1995; Clark and Hillyard, 1996; Hillyard et al., 1996; Wijers et al., 1997).

The first chapter of this thesis reviews the relevant theoretical concepts of space- and object-based selection and the role of Kanizsa illusory objects. We also discussed various views and evidence on how space- and object-based selection might Be related. A satisfactory and coherent theoretical framework which focuses on the relation between space- and object-based selection has not yet been formulated. In order to better understand the relation between these types of selection, ERP may provide valuable information. For instance, in space-based selection models, attention is thought to enhance sensory gain of information at attended locations. In line with this idea, spatial attention has been found to result in modulating effects on the ERP, known as the early exogenous components P1 and N1, which are thought to be generated in extrastriate visual areas.

The general aim of this thesis was to explore the influence of Kanizsa objects as a context on selection, and to use ERPs to gain more insight in the brain processes that are associated with object-based attention. The questions addressed are: 1) are spatial attention effects in performance modulated by the context of illusory objects in which there are only two relevant locations (the cued location and one alternative location)? 2) when there are several alternative locations, besides the cued location, for targets to appear, is spatial distribution of attention altered by the context of (illusory) objects? 3) can the interference of flanking letters on discrimination of a target letter be manipulated by contextual illusory objects? 4) how does the form of illusory object inducers interact with the perception of the form of the illusory object itself?

6.1.1 Chapter 2

In the study presented in chapter two, two spatial cuing experiments were conducted in which illusory objects and so-called Amodal objects were used as a surrounding context. In the first of those experiments, after presentation of the object context (a Kanizsa or Amodal rectangle), an endogenous cue was presented on fixation which always was in the centre of the object, indicating the most probable target location. The possible target locations were to the left or the right within the presented object. It has been suggested in the literature (e.g., Mattingley, Davis, and Driver, 1997) that attention is more likely to spread over the surface of the 'good' percept of the Kanizsa object (leading to reduced effects of spatial cuing) than over Amodal objects. In the second experiment, either one large illusory object was presented (which again could be Amodal or Kanizsa), which comprised both possible target locations (left and right of fixation), or two objects, each comprising one possible location. Colouring of the inducers was used to indicate the most probable location of the target. Contrary to the predictions derived from object-based theories, in neither of the experiments did Kanizsa illusory figures have an effect on performance. As will be discussed in more detail below, it is suggested that object-based selection effects emerge only when there is competition for visual information between two alternative target locations (one within the attended object, one on another object).

6.1.2 Chapter 3

Chapter three uses a well-known paradigm in the literature on object-based selection to test whether object-based effects emerge when more than one alternative target locations are used (Egly, Driver, and Rafal, 1994). In this paradigm, two parallel rectangles are first presented and spatial attention is cued to one of the rectangle ends. After a short delay, a target square is flashed in either the cued location (Valid) or on the other end of the cued rectangle (Invalid Within) or on a rectangle end (but equidistant to the Invalid Within location) of the other rectangle (Invalid Between). Typically, responses to Validly cued targets are quickest, then Invalid Within, followed by Invalid Between targets (Egly, Driver, and Rafal, 1994). In a pilot experiment, we first conducted a behavioral study to verify that object-based effects are also present when using Kanizsa rectangles, in addition to real rectangles. Space-based and object-based cuing effects were observed to be equal in both types of objects. In the second experiment, we used Kanizsa rectangles and contrasted these with Amodal rectangles. Furthermore, we measured ERPs to test whether object-based attention affects the same components as spatial attention does (P1 and N1) and to study the temporal dynamics of object- and space-based selection. The results showed that whereas spatial attention modulated both the P1 (100-140 ms) and the N1 (150-200 ms) amplitudes, object-based attention only had an effect on the N1 amplitude. The results for Amodal and Kanizsa objects were very similar. The N1 component has been associated with perceptual processes such as visual discrimination (Vogel and Luck, 2000). Information at attended locations is better discriminated. The N1 has also been associated with reflexive shifts of attention (Luck et al., 1990; Heinze et al., 1990). As discussed in Chapter 3 (and further below), this latter interpretation of the N1 provides a better explanation for the present effects. Specifically, the N1-effects on Invalid Within and Invalid Between targets are taken to indicate that when a stimulus is not detected at the cued location, spatial attention is preferably redirected to alternative locations within a cued (i.e. the same) object, rather than to alternative locations within other objects. This interpretation is in line with recent ERP studies on object-based attention and with recent behavioral findings suggesting that object context biases search strategies (e.g., Shomstein and Yantis, 2002; 2004; McCarley, Kramer, and Peterson, 2002).

6.1.4 Chapter 4

Chapter four describes an ERP experiment in which Kanizsa objects were used as contexts in an Eriksen-task (Eriksen and Eriksen, 1974). Before the letter array appeared, a Kanizsa illusory object context was presented in an attempt to affect the flanker interference effect. One of the contextual Kanizsa illusory figures was one large rectangle so that the letter array presented over it contained both the target *and* the flanking letters.

This condition was contrasted with conditions in which the Kanizsa illusory figure contexts were smaller so that the target and flanking letters were presented on different object contexts. The expected reduction of flanker interference effects when the Kanizsa contextual objects segregated the target letter from the flankers compared with a letter array which was presented in a large Kanizsa object context was not found. What was found was 1) a difference in ERP signature when the Kanizsa objects were presented (indicating that the objects were differentially processed) and 2) that presentation of the letter array on a context which segregated the target from the flankers evoked larger N1 components compared to presentation of the same letter array on a different context. This suggests that processing of the letter array may be altered by the Kanizsa object context, but that this is not expressed in an effect on performance.

6.1.5 Chapter 5

In chapter five the effect of the relation between the form of the inducing elements of an illusory object and the form of the illusory object itself is investigated. First, a behavioral study was conducted in which the subject's task in one condition was to discriminate the form of the inducing elements (square or circle) and in the other condition to discriminate the form of the illusory object (square or circle). From several lines of evidence suggesting global dominance (see Navon, 1977) , it would be expected that illusory object form identification would interfere with the identification of the form of the inducing elements, whereas form identification of the inducing elements is hardly influenced by the form of the global illusory object (i.e. larger global-to-local interference than local-to-global interference). However, in the present experiment it was observed that judging the form of the inducing elements was not affected by the form of the illusory object. Instead, illusory object form identification was influenced by the form of the local inducers. More errors and slower responses were made when the form of the inducing element referred to the other response hand (i.e. when objects were incompatible) than when the element and illusory object form were compatible.

In a second experiment, we used the same stimuli with a slightly different approach, which aims at ERP patterns rather than at performance measures. Similar illusory objects were used in one condition. In an additional condition real Global objects were used instead of Illusory Global objects. In this paradigm, subjects had to detect a target combination of features (e.g., a Global square with circular inducers). The task to detect a target with a congruent combination of features (e.g., Global square with square inducers or circular Global objects induced by circles) was much easier than when a target with an incongruent feature combination had to be detected (e.g., Global square with circular inducing elements or illusory circles with square inducers).

In addition to these performance data, the ERPs also suggested marked differences between conditions in which the target's Global and Local features were congruent and conditions in which they were incongruent. In conditions in which subjects had to detect a target with congruent features, the ERP suggested that subjects processed Global and Local stimulus features in parallel. That is, a processing negativity associated with stimulus processing was observed for relevant Global features independently from the negativity caused by relevant Local features. This pattern contrasted with the ERP pattern evoked by stimuli presented in the condition in which subjects had to detect a target with incongruent features. In this condition, selective processing of the features started later than in the condition in which the target had congruent features (the difference in onset of feature processing between both conditions was comparable with the difference in target detection between both conditions). Furthermore, the negativity associated with stimulus processing was only observed when both Global and Local features were relevant (i.e. only stimuli with relevant Global *and* Local features evoked a negativity compared to other stimuli). This may indicate that in this condition subjects compared the presented stimulus with a holistic representation of the target stimulus (i.e. the combination of Global and Local features), whereas in the condition in which the target had congruent Global and Local features, subjects could compare the features of the presented stimulus independently with memory traces of the Local and Global target features. These results suggest that selective processing of stimulus features depends strongly on task requirements, similar to what has been shown for differential engagement of early and late selection mechanisms (see for instance Lavie and Tsal, 1994; Lavie, 1995).

6.2 Conclusion and direction for future research

In all of the experiments described in this thesis, similar and clearly visible Kanizsa Illusory objects were used. Indeed, in the experiments in which ERPs were measured, Kanizsa objects evoked distinct potentials, suggesting a distinct object representation. Therefore, the subjects probably clearly perceived the Illusory object form. However, these contextual objects had marginal effects on performance in most of the experiments. This seems surprising with respect to the theoretical proposals and a variety of previous empirical findings reviewed in Chapter 1. Taken at face value, object-based theories would seem to predict that a Kanizsa illusory figure, when actually perceived, should be able to influence attentional selection, which should have resulted in effects on performance.

The unexpected and disappointing absence of object-based effects on performance in most of the experiments we performed may be explained by recent findings. McCarley, Kramer, & Peterson (2002), used the Egly design in which subjects could freely move their eyes to search a target among three distractors. After a peripheral cue, a target display was shown as soon as the subject had redirected his or her gaze from central fixation to one of the possible target positions (in most cases, of course, the cued location). A two choice alternative response had to given to the target manually. In invalidly cued trials, subjects made more and faster eye movements within the cued object than across objects. Critically, when (the manual) RTs were compared for trials in which the subjects' gaze was redirected from a distractor directly to a target, the RT to targets presented on the same object were nearly identical to the RTs to targets presented on the uncued rectangle. Hence, subjects were more inclined to explore the cued rectangle, although discrimination of stimuli presented on uncued locations of the cued objects was not better than that of stimuli which appeared on the uncued rectangle. This suggests that the object cuing effect reflects attention-allocation or a search strategy rather than an automatic tendency of visual attention to covertly spread across an object.

According to the attentional prioritization account of Shomstein and Yantis (2002) object-based effects should emerge only when attention cannot be narrowly focused because multiple locations in the scene are potentially relevant. They first presented two superimposed rectangles (one vertically, one horizontally) which crossed at fixation. In the first four experiments they presented a target letter on fixation. Flanking letters were presented left and right of the target. Notice that these flanking letters were either on the same rectangle (i.e. when the horizontal rectangle was presented on top of the vertical rectangle), or on the other rectangle (i.e. when the vertical rectangle was presented on top of the horizontal rectangle). Interference by flankers which were presented on another rectangle than the target letter did not differ from those presented on the same rectangle. However, in a fifth experiment, attention could not be narrowly focused, because the target could be presented at four possible locations on the rectangles. In this experiment object-based modulation of the flanker effect was observed. Therefore, they suggested that object-based selection may reflect an object-specific attentional prioritization strategy, rather than modulation of an early sensory representation by objects (Shomstein and Yantis, 2002; 2004).

The results of the experiments presented in this thesis are consistent with the notion that object-based selection effects emerge when attention cannot be narrowly focused because multiple locations in the scene are relevant. The results of the experiments discussed in Chapter 2 suggest that this notion can be characterized more specifically. In these experiments only two locations were relevant. Kanizsa Illusory object contexts had no influence on performance in these experiments. This suggests that an attentional shift towards an alternative location is not hampered by crossing an object's boundary, when there is only one alternative location. In the experiments which use the Egly paradigm (Egly, Driver, and Rafal, 1994) relevant information can be presented at more than one alternative location. Typically, targets presented on rectangles which were cued are responded to faster and more accurately than targets presented on uncued rectangles. This suggests that subjects redirect attention preferably within the object on which attention is located than to locations on other objects.

Object-based effects on performance were found in the experiments discussed in Chapter 3. Furthermore, the ERP effects associated with object-based attention (the N1 component) occurred later than the ERP effects associated with space-based attention (the P1). In Chapter 3 it is argued that the N1 modulation by object-based selection can be associated with reflexive attentional shifting (Luck et al., 1990; Heinze et al., 1990; Yamaguchi, Tsuchiya, and Kobayashi, 1995). In recent literature, the N1 has also been associated with discrimination processes (Vogel and Luck, 2000). As discussed above, McCarley et al. (2002) showed that discrimination of target presented on the cued rectangle is not better than of the target presented on the uncued rectangle. Therefore, it seems more likely that the N1 modulation by object selection in this experiment reflects a reflexive shift of attention than altered discriminative power.

The interpretation of the N1 modulation by object-based selection as a reflection of attentional shifting not only converges with the recent experiments discussed above (McCarley, Kramer, and Peterson, 2002; Shomstein and Yantis, 2002; 2004), it can also explain the data from other ERP studies on object-based selection. Weber, Kramer, and Miller (1997) replicated Duncan's experiment (Duncan, 1984) in which two superimposed objects were presented and subjects had to report whether two target characteristics were present. As in Duncan's experiment this was easier when the two target features were on the same object than when they were presented on different (but same location) objects. Importantly, the N1 was *larger* when the features were on different objects, than when they were on the same object. This may reflect that attention has no need to be reallocated in the same object condition (all the relevant information is attended), but that an attentional shift is needed when the target features are on separate objects. When this statement is correct, this would implicate that the attentional shift within the cued object occurs between 150 and 200 ms (in the N1 latency).

Attention could be narrowly focused on the target location in the experiment discussed in Chapter 4, preventing the need to shift attention. In line with the recent evidence discussed above, performance was not influenced by Kanizsa Illusory object contexts. Interestingly however, we observed that the N1 evoked by presentation of the letter array was altered by the figural context. In contrast with discussion in the preceding paragraphs, the N1 in this experiment is unlikely to reflect a reflexive attentional shift. The letter array was presented at least 350 ms. after the subjects were presented with the object display, which indicated the letter array location with 100% probability. This should have been sufficient time to focus attention at the location at which the letter array would be presented (see Cheal & Lyon, 1991). The N1 in this experiment may reflect a change in perceptual organization, without an effect on performance. In a similar vein, McCarley et al. (2002) showed that the discriminative power was not increased on locations to which subjects were more inclined to shift attention to. This illustrates that exploratory behavior of subjects over objects and perceptual factors may occasionally be dissociated from performance.

In the experiments discussed in Chapters 2, 3 and 4, Kanizsa illusory objects were used as surrounding contexts in which relevant information was presented. This contextual role of these objects was similar to that in other studies (e.g., Egly, Driver, and Rafal, 1994; Mattingley, Davis, and Driver, 1997; Moore, Yantis, and Vaughan, 1998; Abrams and Law, 2000). In these studies, the features of the object itself are not relevant to the task the subjects had to perform. The objects were used as a spatial context for the relevant information presented on them. These object-based selection effects may be contrasted with those shown in studies which have investigated how features of an object are selected when subjects have to report another feature of the same object. It was shown that when subjects had to discriminate a feature of an object, other features of the same object were also (partly) selected (e.g., Kramer and Jacobson, 1991; Lavie & Driver, 1996; Duncan, 1984; Vecera and Farah, 1994; Kramer, Weber, and Watson, 1997). That this difference may also reflect different mechanisms of object-based selection can be illustrated by comparison of the experiments of Kramer and Jacobson (1991) and the experiment in Chapter 4. Although these experiments were very similar, only in the former were object-based effects on performance found. In Kramer and Jacobson's studies, the subject's task was to discriminate a feature, for instance the texture, of a central target line. The texture of flanking lines interfered more with discrimination of the target line, when these flanking lines were elements of the same object as the target line, than when they were elements of another object. Presumably, the texture of other parts of the same object also was selected and influenced performance on texture discrimination of the target. In the experiment discussed in Chapter 4, objects were used as surrounding context for a letter array of which subjects had to discriminate a central target letter. In contrast with the experiments of Kramer and Jacobson (1991), these flankers (i.e. letters) and the target were not element of the same object. Shomstein and Yantis (2002) used a very similar design as the experiment discussed in Chapter 4, and reported similar results. This may suggest that multiple features of an attended object are involuntarily selected.

Models such as the biased competition model of Duncan et al. (Desimone and Duncan, 1995; Duncan et al., 1999) might explain how multiple features of the same attended object are more easily selected. This model focuses on the interplay between bottom-up and top-down sources of attention. Bottom-up information processing of each presented stimulus occurs concurrently. For instance, when one blue coloured stimulus is presented between several red coloured stimuli, this stimulus will pop-out in this module and colour as a module also gains competitive weight. Consequently, the stimulus activates other modules so that other features of the same object gain a competitive edge over their within-module competitors. Between modules object-specific features facilitate each other. Therefore, selection involves processing of all the features of the object. Top-down activation biases this competition by behavioral requirements, such as task restrictions. This operates upon the, in this example, visual processing areas by top-down activation. When, in a certain task, objects have to be identified which have a particular colour, the colour module, and a certain colour in particular will be preactivated. Stimuli forming a group, or which are element of an object, may have higher competing values than others, which makes selection more likely. It would be interesting to investigate how the surrounding contextual effects of objects might be simulated in this model.

This within-module competition in conjunction with object-specific between-module facilitation may also explain why object-based effects are larger when realistic objects are used (Watson and Kramer, 1999; Atchley and Kramer, 2001). Experiments which used simple object features (Kramer and Jacobson, 1991; Lavie and Driver, 1996; Duncan, 1984; Vecera and Farah, 1994; Kramer, Weber, and Watson, 1997) the magnitude of the object-based effect expressed in RT is of 20 ms. Sometimes, these small effects are even eliminated. For instance, Lavie and Driver (1996) used a feature discrimination paradigm. Rather than detecting the number of features, they asked the observers to perform a same/different judgment. They presented subject with two intersecting dashed lines. The relevant features were gaps and dots that could appear on one line (same object) or both lines at either a near distance or a far distance (spatially equivalent to the same object condition). In the first three experiments, the same/different judgment was performed more rapidly when both features occupied the same line than when each relevant feature occupied another line. In a fourth experiment they facilitated spatial attention with an exogenous cue. In this last experiment, no object-based effects were observed. Watson and Kramer (1999) also found that when two targets have to be described this is easier and performed faster when they occupy the same object, as compared to when they are presented on separate objects. The objects they used to do this experiment were more realistic, namely two aligned wrenches. Their object-based effects, they noted, were in the magnitude of 90 ms. Atchley and Kramer (2001) attempt was to create as realistic objects as possible. They presented subjects with pipes which could extend into a depth plane. The subjects were told they would be viewing a virtual reality display of pipes in a nuclear power plant and that an accident had occurred which had caused leaks in the pipes. The targets were the leaks in the pipes. In four experiments they found object-based effects of 70 ms or so. Even when they tried to replicate the findings of the fourth experiment of Lavie and Driver (1996) just described, they still observed object-based effects on performance.

How can the relatively large effect that realistic objects have on space- and object-based selection be simulated in the model of Duncan (1999)? Simple objects consist of only a few features (e.g., colour and texture). Realistic objects consist of many features (e.g., colour, semantic predisposition, texture, etc). When these many features mutually facilitate each other's representation, than the spatial features of the object will also become strongly boosted. Therefore, selection of a particular location separated from the object, becomes harder when the object is realistic.

In conclusion, the results reported in this thesis are consistent with recent findings in other laboratories. These findings suggest that subjects preferably shift their attention within objects on which attention was already located. Another important recent finding is that realistic objects can be used to increase the object-based selection effects in comparison with usage of simple objects. Future research may use realistic objects more often to study object-based selection, thereby avoiding the fragility of object-based effects in experiments which used less realistic objects. In this thesis, ERP methods have been shown to usefully contribute to knowledge about object-based attention, especially when more realistic objects will be used.